

Longshore Transport Based on Directional Waves Along North Tamilnadu Coast, India

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ABSTRACT

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The accurate assessment of longshore sediment transport pattern along Nagapattinam-Poompuhar coastline bears significance due to the historical erosion and its geographical location adjoining the sheltered Palk Bay. Directional waves were measured off Nagapattinam coastline for one year to estimate the longshore sediment transport rate. It shows that the transport rate is relatively high about $0.1 \times 10^6 \text{ m}^3/\text{month}$ in November and December and is low showing less than $0.03 \times 10^6 \text{ m}^3/\text{month}$ in March, April and July. Though the annual gross transport is found to be $0.6 \times 10^6 \text{ m}^3/\text{year}$, the annual net transport is very low showing less than $0.006 \times 10^6 \text{ m}^3/\text{year}$ (towards north), indicating the coastline tends to be a nodal drift regime. The temporary rise in wave activities during the cyclonic days often increases the southerly drift, which partly gets deposited in the Palk Bay and causes deficit for the northerly drift.

ADDITIONAL INDEX WORDS: Littoral drift, nodal drift, Indian coast, Palk Bay.

INTRODUCTION

India has a long coastline of about 7000 km bounded by the Bay of Bengal on the east, the Indian Ocean on the south, and the Arabian Sea on the west. Tamilnadu forms on the southeastern peninsular part of India (Figure 1). Wave sheltering effect due to Srilankan Island, shallow Palk Bay, Gulf of Mannar, and long sandy beaches are the typical characteristics of the Tamilnadu coast. These diversification in morphology significantly control the pattern of longshore transport along the Tamilnadu coast. While the beach erosion near Pondicherry and Madras occurs due to man-made littoral barriers, natural processes themselves induce erosion at Kan-yakumari and Nagapattinam. The pattern of longshore transport rate in this region has not yet been investigated in detail due to non availability of data on waves. Earlier works were mostly based on historical ship reports on waves and dredging records (SAXENA *et al.* 1976, CHANDRAMOHAN *et al.* 1990). The factual assessment on sediment transport along Nagapattinam-Poompuhar coastline is vital since it adjoins the sheltered Palk Bay. Any depletion of the supply of littoral sediment to this segment would invariably affect the stability of the northern Tamilnadu coast. In the present study, directional waves have been measured off Nagapattinam for a period of one year and used to estimate the longshore sediment transport rate. The low transport rate, equal north-south drift, excess deposition in Palk Bay and shoreline recession have been discussed.

Study Region

The Nagapattinam—Poompuhar coastline consists of long, narrow and low sandy beaches (Figure 2). The nearshore bathymetry is relatively steep, straight and parallel to the coast. The beach sediments consist of medium to fine sand with considerable placer minerals like Garnet and Ilmenite (CHANDRASEKAR, 1992). The nearshore seabed consists of fine sand, silt and clay. The tides in this region are semi diurnal with an average spring range of 0.67 m and neap range of 0.19 m. Based upon oceanographic climate, three distinct seasons are recognised: i) the southwest monsoon (June to September), ii) the northeast monsoon (October to January) and iii) the fair weather period (February to May). Extreme wave conditions occur during severe tropical cyclones which are frequent in the Bay of Bengal during the northeast monsoon. Excessive sediment deposition and emergence of sand spits/islands have been observed in the Palk Bay (RAO, 1991). Sizable volume of southerly drift accumulates in Palk Bay, which has been evidenced by the growth of large sand spits in the vicinity of Manamelkudi (LOVESON *et al.*, 1990). On the otherhand, the coastal segment of Nagapattinam—Poompuhar has been subjected to consistent erosion since historical times. The Great Chola Dynasty (~316 B.C.) has had the capital at Poompuhar on the bank of Cauvery River confluence and flourished in maritime trade. This entire city is buried in the sea with time and erosion is seen still active along this shoreline. *Manimekalai*, the famed Tamil epics of 2nd century A.D. mentions that then Poompuhar was swallowed and destroyed by sea, due to the wrath of God Indra whose festival had not been celebrated by the city (NANDAKUMAR, 1989).

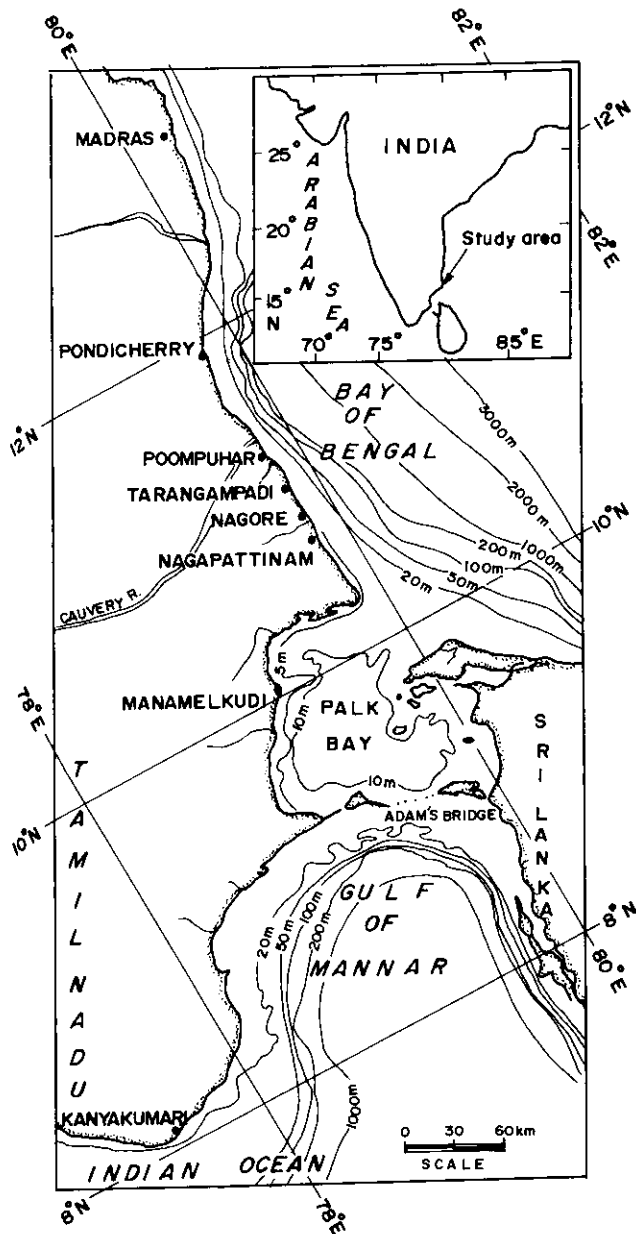


Figure 1. Tamilnadu and Sri Lanka coast.

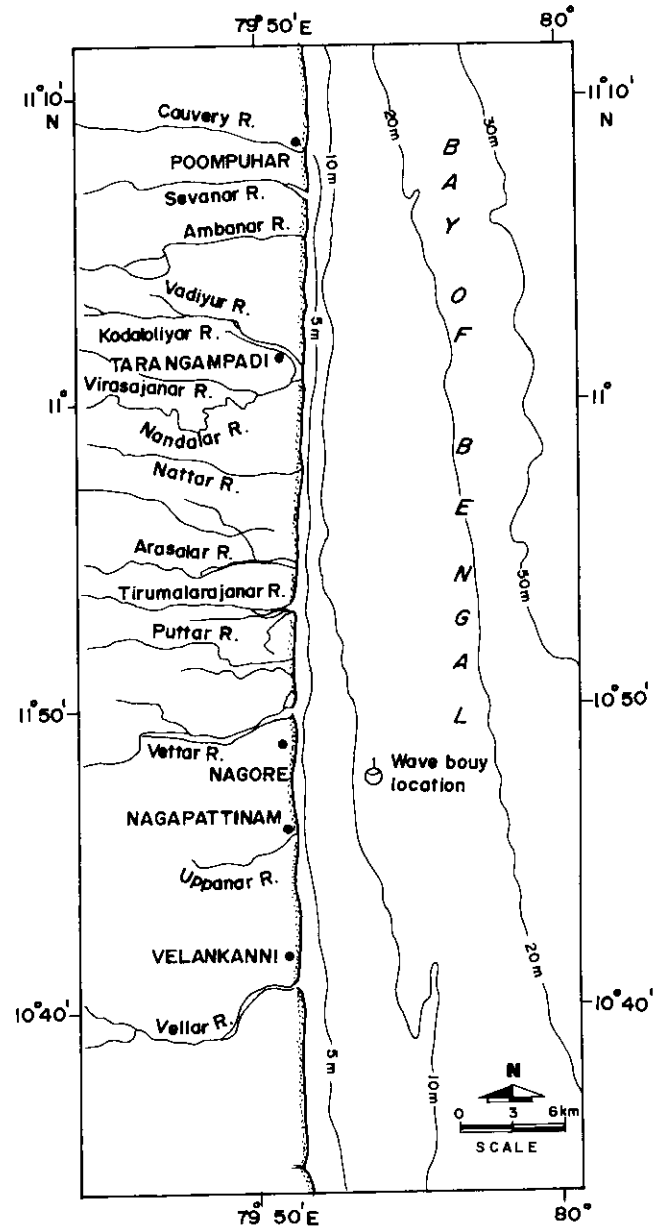


Figure 2. Nagapattinam-Poompuhar coastline.

Measured Directional Waves

To obtain directional wave data, a Datawell directional wave rider buoy was deployed at 15m water depth, at 5 km distance off Nagapattinam (Figure 2). Data on significant wave height (H_s), zero crossing wave period (T_z) and wave direction were recorded for 20 minutes duration, at 3 hour intervals from March 1995 to February 1996 following the methods of Kuik *et al.* (1988). Based on the analysis of these wave data, the predominant wave characteristics were established for each month (Table 1). The significant wave heights persisted between 0.5–1 m during March to October, and 1–

1.5 m from November to February. Highest significant wave height of 2.1 m was recorded in November during the period of one year measurement. The zero crossing wave period predominantly varied 3–8 s in November and December and 3–5 s during the rest of the year. The wave direction (with respect north) mostly prevailed between 60°–120° during November to February, and 90°–120° during the rest of the year.

Breaking Wave Characteristics

To estimate the wave breaking characteristics the wave height and direction measured at 15 m water depth were re-

Table 1. *Predominant wave characteristics off Nagapattinam.*

Month	H_s (m)	T_z (s)	α (deg.)
Jan	1.0–1.5	3–5	60–120
Feb	0.5–1.5	3–5	60–120
Mar	0.5–1.0	3–4	90
Apr	0.5–1.0	3–4	90–120
May	0.5–1.0	3–4	90–120
Jun	0.5–1.0	3–5	90–120
Jul	0.5–1.0	3–5	90–120
Aug	0.5–1.0	3–5	90–120
Sep	0.5–1.0	3–5	90–120
Oct	0.5–1.0	3–7	90–120
Nov	1.0–1.5	3–8	30–120
Dec	1.0–1.5	3–5	60–90

 H_s = significant wave height T_z = zero crossing wave period α = wave direction with respect to north

duced to the wave breaking zone. The wave shoaling coefficients were estimated using small amplitude wave theory. Assuming the contours are straight and parallel, the wave directions measured at 15 m water depth were corrected for refraction effects using Snell's law (SHORE PROTECTION MANUAL, 1984), and the breaker angles were calculated. Accordingly, the 3 hourly variation of breaking significant wave height (H_b), zero crossing wave period (T_z) and the breaking wave angle with respect to the coast are shown in Figure 3.

Surfzone Characteristics

Daily observation on surfzone width and longshore currents was carried out at Nagapattinam beach during March 1995 to February 1996. The observations were carried out while standing on the beach closed to the waterline. Magnitude and direction of the longshore currents were measured using Rhodamine-B dye in the surfzone. The longshore current speed was estimated by measuring the distance moved

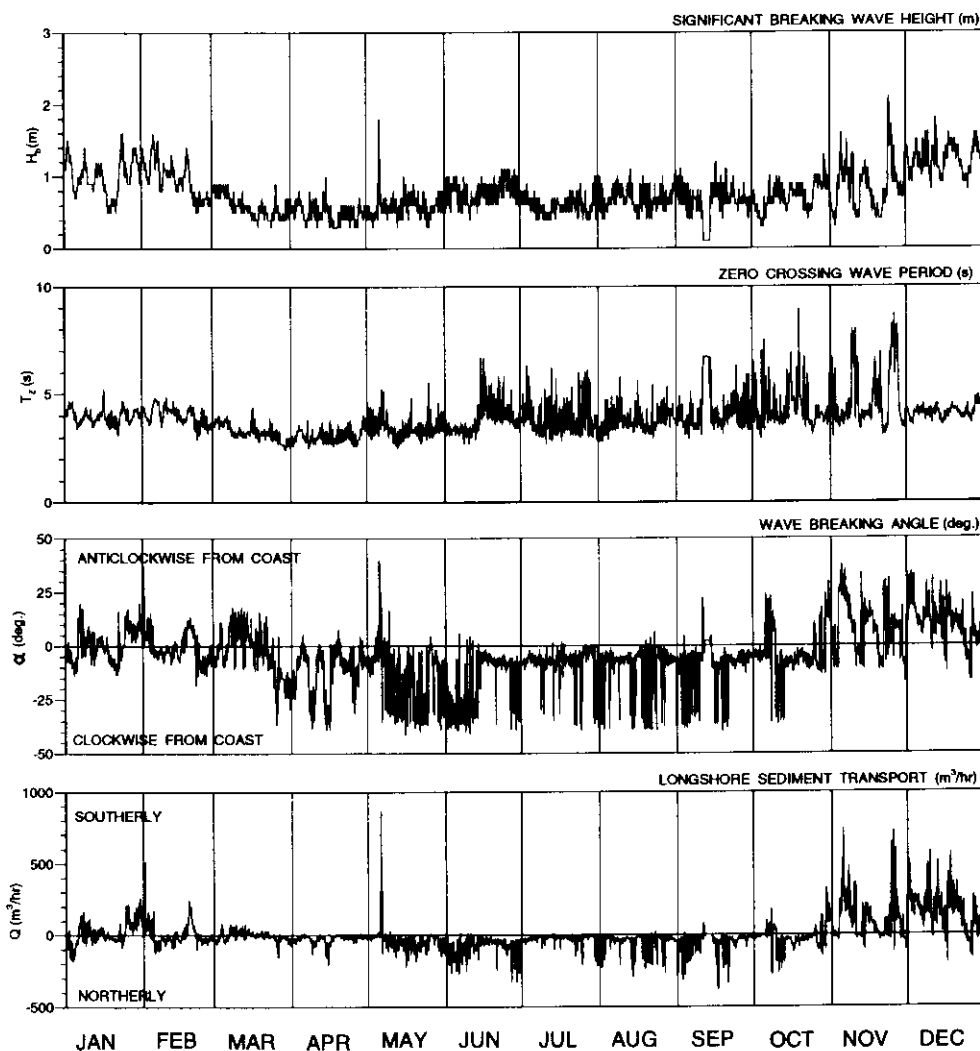


Figure 3. Computed breaker characteristics and the sediment transport rate at Nagapattinam.

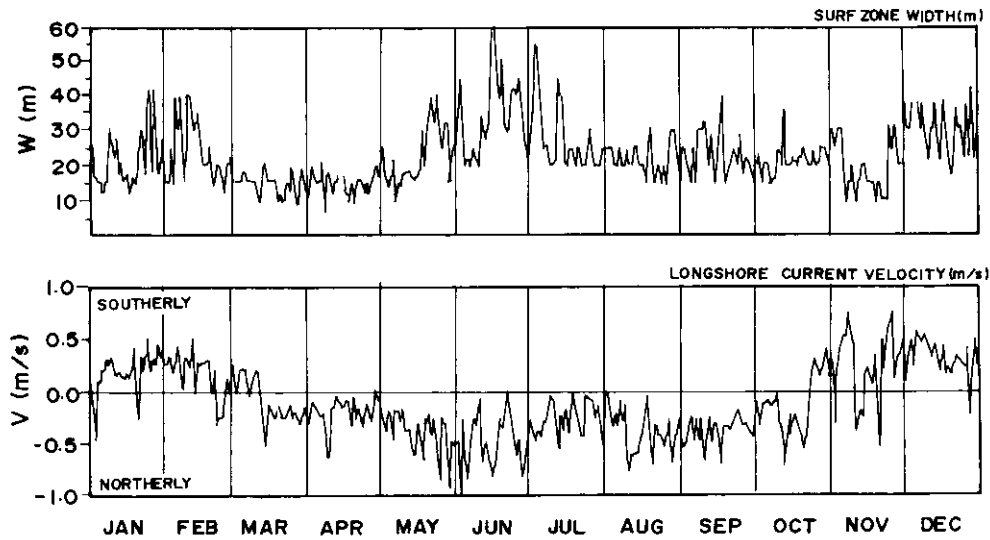


Figure 4. Variation of surfzone parameters at Nagapattinam.

for 2 minutes. The daily variation of surfzone parameters is shown in Figure 4. Plunger type wave breakers were observed in June, November and December, and mostly spilling was found during the rest of the year. The width of the surfzone was more (> 30 m) during May, June and December, between 20–30 m during February and July to November and it was relatively narrow (< 20 m) during January, March and April. The surfzone width was observed to be wider in the month of June. The measured longshore current was northerly during March to October, and southerly from November to February. Strong longshore currents (> 0.6 m/s) were noticed in May, June, November and December. Longshore current was relatively weaker (< 0.3 m/s) from January to April.

Longshore Transport

The longshore transport rate is usually estimated from an empirical equation relating the longshore energy flux in the

breaker zone to the longshore transport rate. Several discussions have already appeared on the selection of suitable equations for estimation of the longshore sediment transport (GRAFF and OVEREEM 1979, WILLIS 1980). CHANDRAMOHAN (1988) has discussed the suitability of the SHORE PROTECTION MANUAL (1975, 1984) equation for estimating the longshore transport rate for the Indian coast. The longshore transport equation rate, Q is given by,

$$Q = 1290 \frac{\rho g^2}{64\pi} T H_b^2 \sin 2\alpha_b \quad (1)$$

Where Q = Volume of longshore transport in m^3/year , ρ = mass density of sea water in kg/m^3 , g = acceleration due to gravity = 9.81 m/s^2 , T = wave period in s, H_b = breaking wave height in m and α_b = breaker angle.

DISCUSSION

The coastline between Nagapattinam and Poompuhar lies almost straight with an inclination of 359° to north (Figure 2). The 3 hourly measured wave characteristics reduced to breaker zone were used in eqn.(1) and the estimated transport Q is shown in Figure 3. The monthly transport is presented in Table 2. It is seen that the transport rate is relatively low along the Nagapattinam—Poompuhar coastline as compared to the rest of the east coast where the transport is well over $1 \times 10^6 \text{ m}^3/\text{year}$ (CHANDRAMOHAN *et al.*, 1990). The transport rate was higher side around $0.1 \times 10^6 \text{ m}^3/\text{month}$ in November and December and was low showing less than $0.03 \times 10^6 \text{ m}^3/\text{month}$ in March, April and July. The monthly distribution of longshore transport rate indicates that the southwest monsoon waves show less significance compared to the northeast monsoon waves. The predominant direction of transport is northerly from March to October and southerly from November to February. These are similar to the results of longshore currents measured. Though the annual gross

Table 2. Estimated longshore transport rate at Nagapattinam.

Month	Northerly (10^6 m^3)	Southerly (10^6 m^3)	Monthly Gross (10^6 m^3)	*Monthly Net (10^6 m^3)
Jan	0.015418	0.029331	0.044749	0.013913
Feb	0.016790	0.019223	0.036013	0.002433
Mar	0.011206	0.008297	0.019503	-0.002910
Apr	0.017255	0.000201	0.017456	-0.017053
May	0.032006	0.008183	0.040189	-0.023824
Jun	0.060797	0.000158	0.060955	-0.060639
Jul	0.022741	0.000030	0.022771	-0.022711
Aug	0.040454	0.000070	0.040524	-0.040385
Sep	0.038743	0.000551	0.039294	-0.038193
Oct	0.029772	0.015413	0.045185	-0.014359
Nov	0.006317	0.087221	0.093538	0.080904
Dec	0.006545	0.123197	0.129742	0.116652
Annual Gross = $0.589919 \times 10^6 \text{ m}^3/\text{year}$				
Annual Net = $-0.006169 \times 10^6 \text{ m}^3/\text{year}$				

* (–) northerly transport

(+) southerly transport

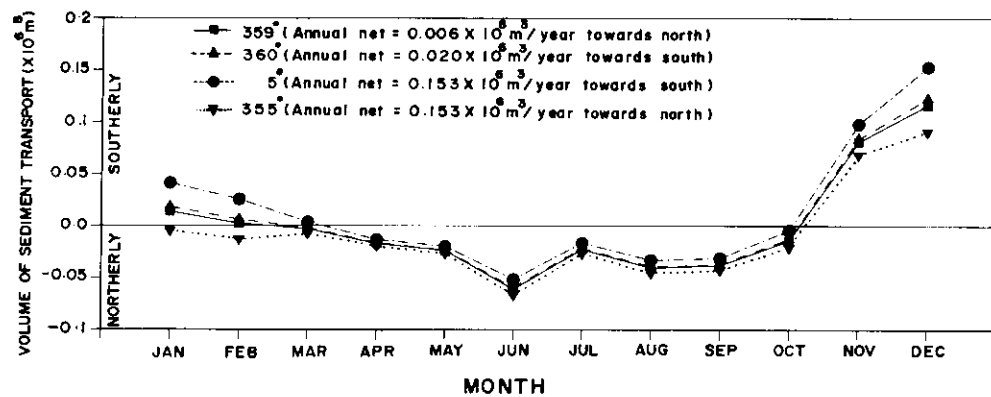


Figure 5. Expected change in computed sediment transport rate for different coastal orientation.

transport is found to be $0.6 \times 10^6 \text{ m}^3/\text{year}$, the annual net transport is very low showing less than $0.006 \times 10^6 \text{ m}^3/\text{year}$ (towards north), indicating the coastline is close to a nodal drift regime having equal longshore transport in north and south directions.

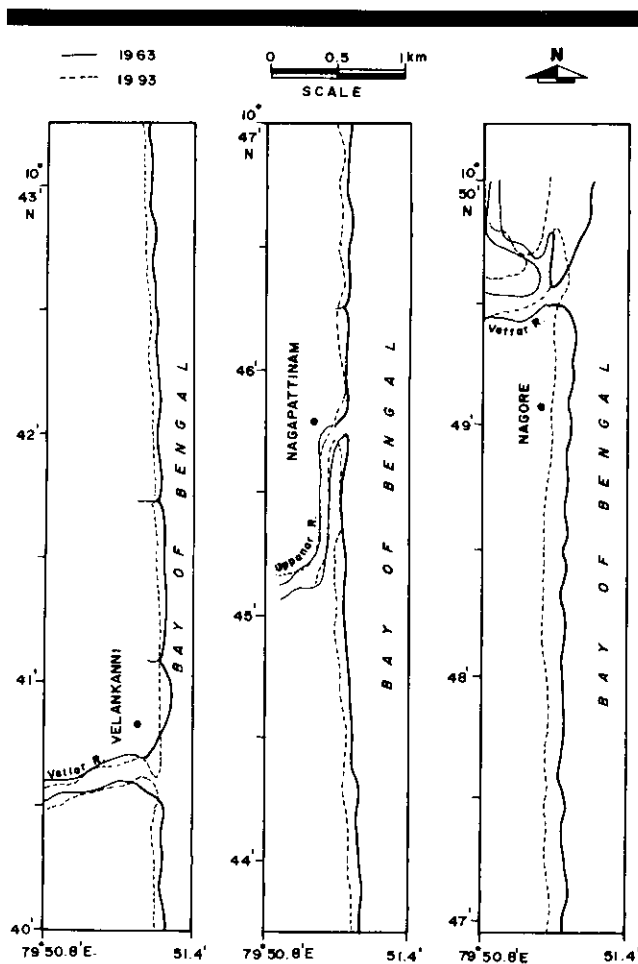


Figure 6. Erosion along the Nagapattinam—Poompuhar coastline.

The present alignment of the coastline is found to be sensitively balanced, since any slight increase in approaching wave angles may significantly increase the volume and also may alter the direction of sediment transport in this region. The volume of southerly drift during 4 months, i.e. in November to February is large and nearly balances the northerly drift taking place in another 8 months, i.e. from March to October. Using the measured wave climate, the anticipated change in the volume and direction of littoral drift, if the coastal orientations deviate $\pm 5^\circ$ to the existing alignment is shown in Figure 5. It is found that for the coastal orientation of 360° to north, i.e. 1° shift from the present orientation, the annual net transport could be opposite, in the southerly direction. It is important to notice that no cyclone had occurred during the study period, which is otherwise common during the northeast monsoon period. Occurrence of such cyclones would considerably increase the volume of sediment transport towards south within a short spell. It has been observed that for the occurrence of every cyclone, there was a permanent loss of beach due to erosion. Comparison with the Indian Naval Hydrographic Charts (Nos. 3006 and 3007) surveyed during 1963 and 1993 indicates that 150–200 m of the coastal belt has been eroded during the last 30 years along the Nagapattinam—Poompuhar coastline (Figure 6).

All earlier studies along the Tamilnadu coast based on visual wave statistics obtained from ship reported data indicated that the north Tamilnadu coast is subjected to a large volume of littoral drift towards north. MANOHAR (1960) reported that the net littoral drift from south to north along the northern Tamilnadu is of the order of $0.4 \times 10^6 \text{ m}^3/\text{year}$. SAXENA et al. (1976), KOMAR (1983), PRASAD and REDDY (1986), and SWAMINATHAN and SETHURATHINAM (1987) stated that striking feature of the east coast of India is its large littoral drift, said to be the largest among the world coastlines. Erosion and deposition on the northern and southern sides respectively of any littoral barrier have been noticed near Madras, Mahabalipuram, Pondicherry, Poompuhar and Nagapattinam (REDDY and HARIHARAN 1979, THOMAS 1989, and USHA and SUBRAMANIAN 1993). They also stated that the Palk Bay region is sheltered with respect to waves and favours the sediment deposition. In contrast to these earlier

studies, the present study shows that the Nagapattinam—Poompuhar coastline is subjected to relatively a low volume of transport and the net annual drift is negligibly small. It is seen that the occurrence of prolonged high wave activity due to cyclone, during northeast monsoon may tend to change the annual net transport towards south. Under such circumstances, the large volume of southerly transport is likely to enter into the adjacent Palk Bay and partly deposit as spits/shoals. Large accumulation of sand and emergence of sand spits/islands in Palk Bay have been widely reported by LOVE-SON *et al.* (1990) and RAO (1991). As the Palk Bay is well protected for southerly waves, no mechanism is set to transport these deposited material towards north. This appears to be the primary reason for the timely depletion of sediment supply to the littoral system and for the intermittent erosion along the Nagapattinam—Poompuhar coastal segment. More study on the formation of shoals and by passing of sediments across Gulf of Mannar and Palk Bay would yield better understanding on the pattern of littoral drift movement along the Tamilnadu Coast.

CONCLUSIONS

The longshore transport along the Tamilnadu coast is more associated with the extent of influence of littoral drift sinks, namely Gulf of Mannar and Palk Bay. The continuous growth of sand spit across Adam's bridge and frequent emergence of shoals in Palk Bay indicate the large scale deposition of littoral material. Consequently, the Nagapattinam—Poompuhar coastline experiences erosion. Careful examination of the sediment transport pattern is very essential to maintain the balance and the stability of the coastline. The present study brings out the nature of the wave climate acting on the coastline. The longshore transport estimate based on the measured waves indicates that the volume of transport is relatively low compared to other part of the east coast. The net annual drift is negligibly small in the northerly direction indicating as a nodal drift region. It is further observed that the occurrence of cyclonic storm during northeast monsoon which is common in the region would considerably increase the southerly drift and may cause the littoral material to deposit in the sink at Palk Bay. Such loss of material is one of the primary reasons for the erosion of the shoreline between Nagapattinam and Poompuhar. The present alignment of the coastline is found to be sensitively balanced, since any slight increase in approaching wave angles may significantly increase the volume and also may alter the direction of sediment transport in this region.

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